Running head: TELEPHONES AS FOMITES

Title: Operating Room Telephone Microbial Flora

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20050615 055

JUN 07 2005

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.

1. AGENCY USE ONLY *(Leave blank)*	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	2.Jun.05	MAJOR REPORT

4. TITLE AND SUBTITLE
OPERATING ROOM TELEPHONE MICROBIAL FLORA

5. FUNDING NUMBERS

6. AUTHOR(S)
CAPT SHINN ANTOINETTE M

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
UNIFORMED SERVICES UNIV OF HEALTH SCIENC

8. PERFORMING ORGANIZATION REPORT NUMBER
CI04-1105

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
THE DEPARTMENT OF THE AIR FORCE
AFIT/CIA, BLDG 125
2950 P STREET
WPAFB OH 45433

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION AVAILABILITY STATEMENT
Unlimited distribution
In Accordance With AFI 35-205/AFIT Sup 1

DISTRIBUTION STATEMENT A
Approved for Public Release
Distribution Unlimited

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

14. SUBJECT TERMS	15. NUMBER OF PAGES	16. PRICE CODE
	24	

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT

Abstract

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Key words: Telephones, Phones, Fomite, Environmental surfaces, Surgical Infection, Acinetobacter, Pseudomonas, and Agrobacterium,

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Introduction

There are approximately 500,000 surgical site infections per year in the United States (1). Nosocomial infections contribute to prolonged antimicrobial treatments, length-of-stays, and even death. The Centers for Disease Control (CDC) reports that in 1999 the most prevalent causes of Surgical Site Infections (SSI) were: *Staphylococcus aureus* (*S. aureus*), Coagulase-negative *Staphylococci* (CNS), *Enterococcus species (spp),* and *Escherichia coli (E. coli)* (2, 3). There have been no published changes to the prevalence of these bacteria in relation to SSI since 1999. In addition, a study published in 2003 reports that extremes of costs for SSIs may exceed $92,363 for patients with Methicillin-resistant *Staphylococcus aureus* (MRSA) SSI(4).

The most common source of SSI are endogenous floras (5), but exogenous floras are also a possible cause of SSI (3, 6). If exogenous floras are causing some surgical site infections, how are they being transmitted? Could the hands of healthcare workers be a source? What other surfaces might be involved via direct or indirect contact with patients? One inanimate item in the operating room (OR) frequently contacted by the hands of staff is the telephone. Could telephones in the OR serve as a source of surgical site infections? An inanimate surface that is implicated in a nosocomial infection is termed as a fomite. Are telephones in the OR fomites? Given the potential impact of nosocomial infections in the perioperative setting, research is needed to describe if the bacteria most frequently involved in SSIs can be found on telephones in the OR. The purpose of this paper is to describe a study conducted to identify and quantify bacterial contamination on telephones in the OR of a large, teaching medical center.

Literature Review

There are many factors associated with nosocomial infections and the chain of infection model provides the best framework for depicting the relationships among these factors and SSIs. The following literature review includes a thorough explanation of the chain of infection model, the relationship among these factors, and a discussion of the current literature on environmental surfaces as fomites.

According to the chain of infection model, a causative agent or pathogen survives within a reservoir, exits the reservoir via a mode of transmission, and enters a susceptible host, thereby causing disease (7). Intervention in any part of this process can stop the transmission of disease. The reservoir can include plants, animals, soil, water, and inanimate surfaces (8). Of these, the most likely exogenous reservoir in the surgical setting is either human or an inanimate surface. Both reservoirs are capable of becoming transmission agents.

Inanimate Surfaces as Reservoirs

The evaluation of inanimate surfaces is best categorized by Spaulding's Classification System. Within this system, items are classified as: Critical, Semi-critical, and Non-critical (9). Critical items present a significant risk of infection if microorganisms are present because these items come in contact with sterile tissues. Semi-critical items pose less risk, because they are in contact with mucous membranes or non-intact skin. Non-critical items are only in contact with intact skin and pose little risk of infection. However, Non-critical items used in patient care can serve as a mode of secondary transmission by providing a reservoir that can contaminate the hands of healthcare workers (10). This mode of transmission, surface to hand transfer of bacteria, is well documented in the literature (11, 12).

Animate Reservoirs as Transfer Agent

Proper hand washing is known as one of the most important steps in preventing infections (9). Despite several studies documenting hands as carriers of infection (13, 14), hand washing compliance has been shown to be as low as 9% for medical intensive care unit (ICU) health care workers and 3% for cardiac surgery ICU health care workers (15). More to the point, as few as 58% of anesthesiologists report that they wash their hands after contact with every patient (16) and compliance with hand-cleansing in a post-anesthesia care unit was shown to be 12.5% (17). If proper hand hygiene is not exercised, items frequently contacted by hands could serve as reservoirs and those reservoirs could further serve to contaminate hands; thereby increasing the chance of spreading infections to patients during hand-to-patient contact.

Environmental Surfaces as Fomites

Even though the importance of cleaning environmental surfaces is well recognized as a standard of care, there is little research available which describes the relationship between the quantity of pathogens present on surfaces and increased nosocomial infection rates (18). Bacteria are capable of transferring antibiotic resistance (19-23), therefore it can be argued that where bacteria are allowed to survive on environmental surfaces, antibiotic resistance could be transferred. It is reasonable to question the cleanliness of environmental surfaces in the surgical setting, especially when as much as 32% of anesthesia equipment has been found to have occult blood present (24).

The role of inanimate surfaces as fomites is not well documented. Some recent studies suggest there is no link between infection rates and surface contamination (25-27) while other studies demonstrate that environmental surfaces and nursing uniforms have increased contamination from patients known to be infected or colonized with MRSA (28, 29). A wide

range of environmental surfaces have been shown to be sources of nosocomial infection, including an electronic ear probe (29), a stretcher frame, a shower handle (28), and operating room surfaces (30). In order to determine the likelihood of bacterial presence on telephones and subsequent transfer via hands, the literature was reviewed to identify survival times of the bacteria most frequently implicated in surgical site infections on hands and inanimate surfaces. These bacteria are: *S. aureus,* CNS, *Enterococcus spp,* and *E. coli.* The literature review also included MRSA and Vancomycin-resistant *Enterococcus (VRE)* as both of these bacteria are variants of *S. aureus and Enterococcus spp.* Few studies have examined bacterial growth on telephones; therefore studies using plastic surfaces were also examined.

Table 1 is a compilation of the literature review and is reflective of experimental and quasi-experimental studies dating back to 1989. While some of the studies are dated, in many cases these studies are either landmark or sole source references. Each of the studies presented in Table 1 used different inoculum concentrations and techniques, and provided us with evidence that bacteria might be present on OR telephones. Based on this review, time alone will not eliminate bacteria sufficiently. The importance of hand washing, aseptic technique, and surface decontamination was evident.

{Please insert "Table 1 Bacterial Survival on Surfaces"} (31-37)

In one study conducted to document environmental surfaces and hands of healthcare workers as reservoirs, 26 telephones were cultured in an ICU and researchers found *S. aureus, Acinetobacter calcoaceticus (A. calcoaceticus), and Pseudomonas spp* (35). In another study of Non-critical items frequently in contact with hands of staff in the hospital, 20 telephones from the OR, ICU, Recovery, and emergency room (ER) were cultured, none of which resulted in the identification of gram-negative bacteria being identified (38). Cozanitis, Grant, & Makela

(1978) cultured 11 telephones in an ICU and identified CNS, Coagulase-positive *Staphylococcus*, gram-positive rods and alpha-hemolytic *Streptococcus* (39). Lastly, a study conducted to identify the bacteria on public telephone hand-pieces at a high school showed increasing numbers of bacteria on telephones from morning to afternoon with CNS being the predominant bacteria identified (40).

The literature review has shown the potential for bacteria to be present on telephones for variable lengths of time and has demonstrated that there is frequently a lack of hand washing and decontamination of environmental surfaces by hospital staff. Additionally, inanimate surfaces have been implicated in infections. In a study conducted by Rusin, Maxwell, and Gerba (2002) a link is clearly created between the transfer of bacteria from telephones to hands and from hands to other skin surfaces. Rusin et al. demonstrated that *Micrococcus luteus (M. luteus)* can be transferred from telephones to hands with approximately 41% efficiency and from hands to the mouth at the same rate of 41% (41).

Methods

Design

The purpose of this descriptive study was to determine if the bacteria most frequently involved in SSI could be found on telephones in the OR of a large teaching medical center. This study focused exclusively on *S. aureus,* CNS, *Enterococcus spp, E. coli*, MRSA and VRE.

Sample and Setting

A quota based convenience sample of 30 cultures from telephones within the ORs at the medical center was utilized. Despite our goal of 30 cultures, only 26 cultures were obtained from telephones within 14 operating rooms and two sub-sterile rooms. Two control cultures and two double cultures were also collected. Specimen collection was divided between two days that

were separated by 19 days in order to decrease the likelihood that perioperative personnel might alter hand washing, aseptic techniques, and environmental disinfection, because they were aware of our study and data collection (42). This research protocol was approved by the Institutional Review Boards of the medical center and the Uniformed Services University of Health Sciences.

Specimen Collection and Analysis Procedures

In order to ensure precision in the collection of data, researchers oriented to the medical center's lab and became familiar with testing supplies and procedures. With the assistance of the Microbiologist Associate Investigator, a guideline was developed for all testing procedures. This guideline is divided into two algorithms. These algorithms are depicted in Figure 1 the "Bacteria Identification Algorithm for *E. coli*" and Figure 2 the "Bacteria Identification Algorithm for Gram-positive Cocci". These algorithms were adapted from algorithms found in "The Textbook of Diagnostic Microbiology" (43). The guideline was incorporated into a standardized specimen data collection and analysis sheet for use in recording the identification and interpretation of bacteria. The data collection sheet was utilized to capture data related to: surgical service, the time of day when cultures were collected, location of the telephone in the perioperative environment, surgical case number, and OR temperature and OR humidity at the time of sampling. Basic laboratory skills of researchers were evaluated during a practical exam utilizing eight known bacterial isolates.

Cultures were taken from OR telephones at the end of surgical cases to eliminate unnecessary traffic through the surgical area and prior to staff cleaning of the surgical suites. Cultures were taken in the same manner by all three investigators wearing sterile gloves. All four sides of the telephone hand piece handles were swabbed. The posterior swab path included one vertical pass from earpiece to mouthpiece while holding the swab on its side and rotating or

rolling it across the surface. Remel Bacti-Swabs with non-nutritive modified Stuart's Medium were used to obtain bacterial sampling. Validity and reliability testing was obtained by random double culturing and random control culturing techniques. The double culture technique included the swabbing of telephones in the manner described previously with two consecutive culturettes attempting to eliminate path over-run. These culturettes were labeled so that one investigator was blinded to the source. One control culture was randomly selected for each culture batch. The control culturettes were opened and re-sealed without exposure to contaminants.

After sampling, the swabs were returned aseptically to their cases, labeled and numbered sequentially. Swabs were carried to the lab within 15 minutes of sampling. All samples were streaked for isolation onto tripticase soy agar with 5% sheep blood agar (Remel, reference # 01202), chocolate agar (Remel, reference # 01302), and MacConkey agar (Remel reference # 01552), respectively. The agar plates were incubated at 35 degrees Celsius (95 degrees Fahrenheit) for 24 hours. Chocolate and blood agar plates were incubated in 4% carbon dioxide (CO_2) while MacConkey agar plates were incubated in 1.2 % CO_2. After the first 24 hours, the entire bacterial floras were visually quantified into the number of colonies present. If no colonies were present at 24 hours, confirmation was performed at 48 hours.

While blood agar plates would support the growth of *S. aureus,* MRSA, CNS, *Enterococcus spp,* VRE, and *E. coli,* there was an ethical obligation to rule out other bacteria capable of causing nosocomial infections. Chocolate and MacConkey agar was utilized to rule out: *Acinetobacter spp*, *Pseudomonas aeruginosa (P. aeruginosa)*, *Haemophilus influenza* (*H. influenza*) and *Neisseria gonorrhea* (*N. gonorrhea*).

Please refer to the "Bacterial Identification Algorithm for *E. coli*" (Figure 1) and the

"Bacterial Identification Algorithm for Gram-positive Cocci" (Figure 2) for a pictorial representation of the testing methods outlined in this paragraph. *S. aureus,* MRSA, CNS, *Enterococcus spp,* VRE, and *E. coli* were identified by: 1) shape- spherical (coccus), rod-like (bacillus), or spiral (spirochete); and 2) cell wall- gram-positive or gram-negative as seen with gram stain. Gram-negative rods were tested for oxidase (Remel, ref #425506) and indole (Remel, ref #21245) reaction. Positive oxidase and negative indole results ruled out *E. coli* and were tested further to rule out *A. calcoaceticus-baumannii* and *P. aeruginosa.* Gram-positive bacteria were initially tested using 3% hydrogen peroxide for catalase testing, which was used to differentiate group 1 (*Micrococcus*, CNS, *S. aureus,* and MRSA) from group 2 bacteria (*Enterococcus spp.* and other *Streptococcaceae*). Group 1 bacteria were then tested with Remel Staphaurex Plus (ref # 30950102) to rule in *S. aureus.* Bacteria that were negative for Staphaurex Plus were then tested with the Microdase test (Remel, ref # 21132) to differentiate CNS from *Micrococcus spp.* Catalase negative bacteria were analyzed using the Boule Phadebact D test to differentiate potential *Enterococcus* from other *Streptococcus spp.*

The Vitek system version 7.02 was used with BioMerieux Gram Positive Identification (GPI) and Gram-negative Identification + (GNI+) cards to identify *A. calcoaceticus-baumannii* complex, *Agrobacterium radiobacter/tumefaciens* (*A. radiobacter/tumefaciens*), and 9 of the 43 isolates of CNS. A single double culture of CNS was also analyzed via GPI card. Identification of *P. aeruginosa* was based on the following test results: gram-negative rod, oxidase positive, catalase positive, presence of motility, and growth at 42 degrees Celsius (107.6 degrees Fahrenheit) in tripticase soy broth (TSB). The methods described above are in compliance with standard culture technique (44, 45).

The counting of colonies was performed by two investigators individually and digital

photos were taken. Additionally, the surface area of the four vertical swabbing paths was calculated to determine Colony Forming Units (CFU)/centimeter squared (cm^2). The maximum swab path width was measured at 3 mm. The length or distance of this path was measured at 95.6 cm. To find the surface area in cm^2, the length (95.6 cm) was multiplied by width (0.3 cm) for a total of 28.7 cm^2, which is nearly equivalent to the surface area of a RODAC agar plate with a 6 cm diameter ($3.14 \times 3^2 = 28.26$ cm^2). Data were entered into a spreadsheet by two investigators individually, using the completed specimen data collection and analysis sheet. A test of inter-rater reliability revealed 100% agreement between two investigators on all data entered into the two separate spreadsheets.

Laboratory and Equipment

The lab used was accredited by the Commission of Laboratory Accreditation of the College of American Pathologists (CAP) in 2004. The reliability and validity of the Vitek system is well established among medical laboratories. Quality Controls (QC) were conducted on all identification card lots used in this study. Digital photographs were taken using an Olympus D-380 camera with 2.0 mega pixels effect and five times digital zoom.

Proficiency testing for the Vitek was performed three times during the year of this study. At the time of preparation of this paper, test results were only available for 2 of the 3 proficiency tests. These proficiency tests showed $\geq$ 86 % accuracy of bacterial identification and $\geq$ 92% performance satisfaction with 100% antigen detection. This level of testing is in accordance with CAP accreditation. The Vitek system is approved by the Food and Drug Administration (46) for both gram-positive and gram-negative bacterial identification and sensitivity testing (1991 &1996).

Phenotypic Testing Agents

Several phenotypic testing agents were used while conducting this study. None of the agents were used beyond their expiration dates. The same lot numbers among agar plates, culturettes, Vitek cards and all other supplies were utilized. The only exception to this was the Microdase test, which did change lot numbers during the second batch of testing. A brief literature review of the testing agents is presented in the following Table 2 "Phenotypic Testing Agents" to demonstrate reliability and validity.

{Please insert Table 2 "Phenotypic Testing Agents"} (47-52)

As outlined in Table 2, *Staphylococcus (S.) lentus, S. sciuri, and S. vitulus* can give a positive Microdase reaction. The impact is probably minimal because in an evaluation of CNS infections, 86 cultures revealed one *S. sciuri* and no *S. lentus* or *S. vitulus* (53). The Phadebact D test was found in one study to be 100% effective in identifying Group D *Streptococcus* (54). Unfortunately, only 80% of *Enterococcus* can be identified by group D antigen testing (45). The catalase, Kovacs indole, modified oxidase, and oxidase tests are standard testing agents for the identification of bacteria (45).

Statistical Analysis

Data analyses were performed using the Statistical Package for the Social Sciences (SPSS) version 12.0. Descriptive statistics (frequencies and means) were used to summarize and describe the variables in the study.

Findings

Of the six bacteria this study attempted to identify, only CNS was found. Additionally, *A. calcoaceticus-baumannii* complex, *P. aeruginosa*, *A. radiobacter/tumefaciens*, *Micrococcus*, *Streptococcus* non-group D, and one unidentified gram–negative rod were found. Chart 1

summarizes the types and number of bacterial isolates discovered. Only the first culture results for telephones that were double cultured are included in Chart 1 to avoid over-representation of isolates.

{Please insert Chart 1 "Bacteria Cultured From Telephones"}

The "Summary of Study Variables and Characteristics" table (Table 3) summarizes the five variables that remained in the study after the removal of the temperature and humidity variables. The humidity and temperature data were not included due to a lack of standardized measuring instruments. In Table 3, the acronym "BAP" refers to tripticase soy blood agar plates and the number of colonies identified; "CAP" refers to chocolate agar plates; and "MAC" refers to MacConkey agar plates. An absence of colonies at both 24 and 48 hours is indicated by "0,0". In Table 3 the word "Total" refers to a cumulative total of all colonies identified among the three growth mediums of BAP, CAP and MAC. "CFU/cm^2" refers to the number of colony forming units identified per centimeter squared, as determined by a swab path surface area of 28.6875 cm^2. "Service" refers to the surgical case type that had occurred in the OR just prior to sampling. "Time of Day" refers to whether specimens were collected in the a.m. or p.m. "Culture Location" refers to the area that contained the telephone, which was cultured (i.e., OR Suite or Sub-sterile Room). "Case #" refers to the surgical case sequence in the room during culturing (i.e. 1st, 2nd or 3rd case of the day).

{Please insert Table 3 "Summary of Study Variables and Characteristics"}

The majority of samples were collected in the a.m. (61.5%) versus p.m. (38.5%). The largest numbers of specimens were obtained from the first surgical case of the day (65.4%), followed by the second case at 30.8%, and the third case at 3.8%. The top five surgical services operating within the rooms where the telephone cultures were obtained were: Orthopedics at

42.3%, Ophthalmology at 15.4%, General Surgery at 11.5%, and Cardiothoracic and Genitourinary Surgery both at 7.7 %. The double cultures from data collection day one and two revealed CNS of similar quantities and on data collection day two, testing with the Vitek and GPI cards revealed the same Genus and Species, *Staphylococcus epidermidis.* One telephone (specimen #9910 in Table 3) was cultured after the room had been cleaned. This specimen had the second highest number of colony forming units per cm^2 at 2.16.

Discussion

During this study, *S. aureus, Enterococcus spp.,* and *E. coli* were not detected on telephones in the OR. The inability to find *Enterococcus spp.* may be related to the limitations previously described for the Phadebact D test. Thus, in each of the three isolates recorded as non-group D *Streptococcus*, *Enterococcus* may have been missed. Additionally, colony counts for bacteria were low in comparison to levels recorded for public school telephones (40), horizontal surfaces in OR rooms (5.86-6.98 CFU/cm^2) (27), stethoscopes (158 CFUs) (12), hospital pagers (39-153 CFUs) (55), and telephones in the ICU (7-282 CFU) (39). The mean number of colonies found on phones in the sample set of this study was 23.3 CFU or 0.81CFU/cm^2 / phone.

The only environmental surface contamination guidelines that were found were based on the use of RODAC plates. The guidance describes that floors with microbial contamination greater than 50 colonies per plate relate to poor cleanliness (56). In this study, only four samples exceeded that amount. Those four samples did not contain the isolates of: *Acinetobacter, Pseudomonas*, or *Agrobacterium.* Again, our findings were generally low in comparison to other studies. This is largely due to sampling technique variations. For instance, the Yalowitz study swabbed the entire surface of the telephones and would be expected to have higher colony

forming units. Only counting bacteria at 24 hours may have resulted in a failure to identify some slow growing bacteria. If an agar plate contained no colonies at 24 hours, this was re-evaluated at 48 hours. Other studies counted bacteria on all plates at 24 and 48 hours (35). The inability to find *S. aureus* parallels similar difficulties in another study that were remedied by using broth to support environmental cultures which led to increasing MRSA findings by a factor of two (57). Similarly, Rafferty and Pancoast (1984) were only able to isolate *S. aureus* twice out of 114 specimens. The inability to find *E. coli* on telephones is consistent with a study by Rafferty and Pancoast (1984) that found no gram-negative bacteria on 20 telephones in the OR, ICU, Recovery and ER areas (38). Additionally, *E. coli* was found in the literature review to have a relatively short life span on environmental surfaces (36, 37), which may explain its absence.

The bacterium most frequently isolated in this study was CNS. CNS and *S. aureus* are the most commonly implicated bacteria in surgical site infections, 20% and 14% respectively (3). Subsequently, CNS are one of the most frequently isolated bacteria in the laboratory (58). These bacteria are of little virulence (59) but are frequently implicated as the cause of infections in patients who are immunocompromised or have medical implants (60-63). A high prevalence of CNS on telephones is consistent with Cozanitis et al. in their finding of CNS on all the telephones that they cultured (39).

Serendipitous Findings

These results differ from the findings obtained by Rafferty and Pancoast (1984) in that three other gram-negative bacteria were present on telephones, namely: *A. calcoaceticus-baumannii* complex, *P. aeruginosa,* and *A. radiobacter/tumefaciens*. Similarly, Getchell-White et al. were also able to find *Acinetobacter* and *Pseudomonas* but they were also able to find three isolates of *S. aureus* from 26 telephone cultures. They utilized RODAC impression agar plates

which eliminate the number of times that bacteria are transferred (RODAC plates are a direct transfer technique). Undoubtedly, some of the bacteria remained in our culture swabs and were not accounted for. Had RODAC plates been utilized, bacterial counts might have been higher.

Acinetobacter, P. aeruginosa, A. radiobacter/tumefaciens and *Micorococcus* have been implicated in nosocomial infections (64-73) but, these bacteria are predominantly involved in infections of the immunocompromised host (45, 64, 65, 74-76). It is likely that the discovery of these bacteria could have been avoided with simple hand washing, surface disinfection and basic aseptic techniques.

Recommendations for improvement

During the collection of temperature and humidity data within the surgical rooms, the gauges already present in rooms were utilized. Because no standardized method of measurement was used, these data were removed from this study. Future studies could utilize a portable device to ensure standardized measurement. A larger sample size would help to validate data and provide a basis for inferential statistics. Additionally, specimen collection may be more efficient with RODAC impression agar plates, due to the advantages of a direct transfer technique. Colonies should be counted at both 24 and 48 hours in an attempt to recognize slow growing bacteria. In our study, morphologic examination was conducted at 24 hours. However, the separation of colonies based on morphologic examination is much easier at 48 hours. By that time, hemolytic rings are clearly visible and colonies have had ample time to differentiate themselves. While some CNS have been shown to be methicillin resistant (3, 77, 78), it may be beneficial to determine the frequency of this resistance. Finally, adding broth to support environmental cultures could lead to increased MRSA findings as supported by the study conducted by Boyce et al. (57).

Implications and *Conclusion*

The reader should be cautious in drawing conclusions based on a convenience sample from only one medical center in which surgical technologists and circulators perform cleaning between cases. The data in this study may have been impacted by increased workloads. During the time of sampling the number of surgical cases increased 25.7% between the first and second sampling. During the entire month of sampling, there was an increase in the number of surgical cases by 37.9% from the previous year. Additionally, the quantity of bacteria needed to cause disease is unclear. Hinton, Maltman, and Orr were able to show that fresh *Staphylococci* intramuscular injections of 100,000 cells could cause infections in 20% of mice while dried *Staphylococci* injections of 400,000 cells caused infections in 10% of mice (79). However, the CFUs were low in comparison to the Hinton, Maltman, and Orr (1960) study and thus conclusions related to disease can not be established.

There is a need for heightened awareness of cleaning procedures and standard precautions. It seems reasonable to assume that surface contamination in the form of *Acinetobacter* or *Pseudomonas* in the surgical suite is a risk to both staff and patients. While a case can be made for cleaning, it must be emphasized that cleaning needs to be done correctly. When bacteria are subjected to sub-lethal levels of disinfectants, they can become resistant to antibiotics (57, 69). The current guidance by the Association of periOperative Registered Nurses (AORN) for environmental cleaning includes terminally cleaning telephones at the end of the day (18). Additionally, AORN describes that such cleaning should occur when equipment is visibly soiled. In our study, one telephone (specimen #9910 in Table 3) was cultured after the room had been cleaned (between cases). This specimen had the second highest number of colony forming units per cm^2 at 2.16. This finding is particularly disturbing and raises the

question: "Should telephones and other objects frequently contacted by hands in the perioperative environment be cleaned between cases rather than at the end of the day?" More importantly, it is the initial contamination of telephones rather than the cleaning that is concerning. Standard precautions require workers to wear gloves when the possibility of exposure to body fluids exists. Upon removing gloves, hands should be washed (75). The obvious conundrum for OR personnel follows: a circulating nurse must touch soiled materials, leaving the room decreases positive air pressure and places patients at risk for infection (18) and running water is not available in the surgical suite. A possible solution may include waterless hand-cleaner in surgical suites. Ultimately, the cleanliness of the surgical suite is the responsibility of perioperative nurses (18). Perioperative managers in concert with Infection Control Officers must ensure that Environmental Protection Agency (EPA) approved hospital disinfectants are both appropriate for emerging resistant bacteria and are being utilized correctly. Close attention must be applied to these key processes and focused to include aseptic principles and standard precautions.

Future research may seek to: measure hand washing compliance in the surgical suite; quantify the number of varying bacteria that can be transferred from surfaces to incisions via gloved hands and cause infection in mice; frequency with which operating room personnel contact surfaces with gloves after performing the function requiring the use of those gloves; and/or quantify contamination of other objects frequently contacted by hands such as door handles or computer keyboards. Recent literature reports that antibiotic bacteria such as VRE and MRSA can survive and even grow from hours to days on computer keyboards (80) .

{Please insert Figure 1 and Figure 2}

Acknowledgments

We would like to thank the Uniformed Services University of Health Sciences for the grant provided for our research. We would also like to thank Dr. S. Bibb as our research committee chair. Dr. Bibb's guidance has been invaluable. The opinions expressed in this article are those of the authors and do not reflect the official policy or position of the Department of Defense, nor the United States Government.

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Reported by Miranda Hitti of Fox News.

Table 1 Bacteria Survival on Surfaces

Type of Bacteria	Bacteria Survival Time on Hands	Bacteria Survival Time on Inanimate Surfaces	Author	Year	Type of Study
Enterococcus spp	Gloved and ungloved hands 60 min (29)	1. Plastic = 68 to 90 days	Neely and Maley (32)	2000	Quasi-experimental
		2. Telephone = 60 min	Noskin, et al. (31)	1995	Quasi-experimental
		3. PVC = 1 wk to 4 months	Wendt, et al. (33)	1998	Quasi-experimental
VRE	Gloved and ungloved hands 60 min (29)	1. Counter = 58 days	Bonilla, Zervos, Kauffman (34)	1996	Quasi-experimental
		2. Telephone = 60 min	Noskin, et al. (31)	1995	Quasi-experimental
		3. PVC = 1 wk to 4 months	Wendt, et al. (33)	1998	Quasi-experimental
S. aureus	Known skin flora.	1. Plastic = 22 to >90 days	Neely and Maley (32)	2000	Quasi-experimental
		2. Formica = 2 days	Getchell-White et al. (35)	1989	Quasi-experimental
MRSA	Known to survive as skin flora particularly in nares.	1. Plastic = 40 to 51 days	Neely and Maley (32)	2000	Quasi-experimental
E. coli	6 min (34)	1. Glass = 15 min	Fryklund, Tullus, Burman (36)	1995	Experimental
		2. Polystyrene tubes = 3 days	Smith, Eng, and Padberg (37)	1996	Quasi-experimental
CNS	Known skin flora.	1. Plastic = 41to >90 days	Neely and Maley (32)	2000	Quasi-experimental

Table 2 Phenotypic Testing Agents

Test	**Use**	**Accuracy**	**Comment / Reference**
Staphaurex Plus	Identify *Staph. aureus*	94%	(47,48)
Vitek GNI + card	Identify Gram Negative Bacteria	85%	(49)
Vitek GPI card	Identify Gram Positive Bacteria	92%	(50)
Microdase	Differentiate between *Micrococcus* and CNS.	99%	*Staphylococcus (S.) lentus, S. sciuri, and S. vitulus* can produce a false positive. (51, 52)
Phadebact D	Identify Group D *Streptococcus* including *Enterococcus*	100%	Only 80% of Enterococcus react with testing agent.

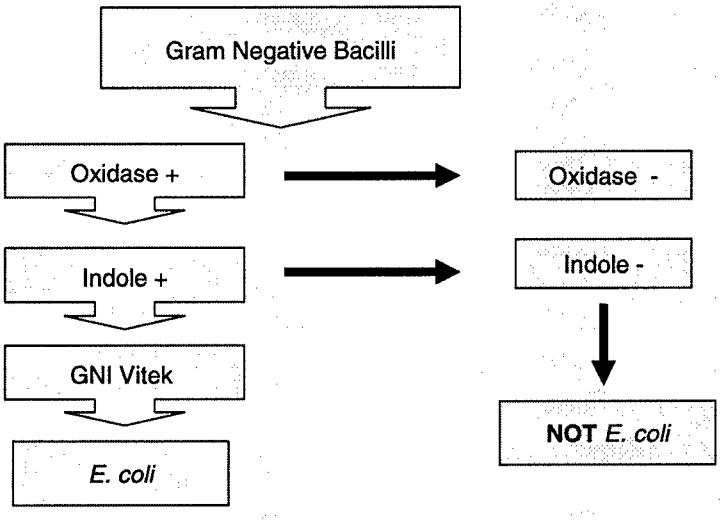
Table 3 Summary of Study Variables and Characteristics

Day 1 Specimen Collection	BAP	CAP	MAC	Total	CFU/cm^2	Service	Time of Day	Culture Location	Case #
9901	25	26	0,0	51	1.78	GEN	a.m.	OR Suite	2
9902	5	3	0,0	8	0.28	NEURO	a.m.	Sub-sterile	2
9903 DBL	3	3	0,0	6	0.21	PLAST	p.m.	OR Suite	1
9904 DBL	6	7	0,0	13	0.45	PLAST	p.m.	OR Suite	1
9905	8	6	0,0	14	0.49	GEN	p.m.	Sub-sterile	2
9906	14	3	0,0	17	0.59	ORTHO	p.m.	OR Suite	1
9907	0,0	0,0	0,0	0	0.00	EYE	a.m.	OR Suite	2
9908 Control	0,0	0,0	0,0	0	0.00	N/A	N/A	N/A	N/A
9909	1	1	0,0	2	0.07	ORTHO	p.m.	OR Suite	2
9910 [(a)]	47	15	0,0	62	2.16	ORTHO	p.m.	OR Suite	1
9911	18	4	0,0	22	0.77	CT	p.m.	OR Suite	3
9912	31	19	0,0	50	1.74	EYE	p.m.	OR Suite	1
9913	30	13	0,0	43	1.50	OMF	p.m.	OR Suite	1
Day 2 Specimen Collection	**BAP**	**CAP**	**MAC**	**Total**	**CFU/cm^2**	**Service**	**Time of Day**	**Culture Location**	**Case #**
9918	6	9	0,0	15	0.52	ORTHO	a.m.	Sub-sterile	1
9919	20	2	0,0	22	0.77	ENT	a.m.	OR Suite	1
9920 Control	0,0	0,0	0,0	0	0.00	N/A	N/A	N/A	N/A
9921	1	0,0	0,0	1	0.03	EYE	a.m.	OR Suite	2
9922	27	10	0,0	37	1.29	GEN	a.m.	Sub-sterile	1
9923 DBL	3	3	0,0	6	0.21	ORTHO	a.m.	OR Suite	1
9924 DBL	5	0,0	0,0	5	0.17	ORTHO	a.m.	OR Suite	1
9925	6	0,0	0,0	6	0.21	EYE	a.m.	OR Suite	1
9926	17	2	0,0	19	0.66	ORTHO	a.m.	OR Suite	1
9927	53	6	0,0	59	2.06	ORTHO	a.m.	OR Suite	1
9928	7	3	0,0	10	0.35	GU	a.m.	OR Suite	1
9929	1	1	0,0	2	0.07	GU	a.m.	OR Suite	2
9930	19	9	0,0	28	0.98	ORTHO	a.m.	OR Suite	1
9931	28	35	0,0	63	2.20	ORTHO	a.m.	OR Suite	2
9932	7	9	1,1	17	0.59	ORTHO	a.m.	OR Suite	1
9933	24	6	0,0	30	1.05	CT	a.m.	OR Suite	1
9934	11	6	0,0	17	0.59	ORTHO	a.m.	OR Suite	1

Note. Specimen Collection was divided among two days that were separated by 19 days.

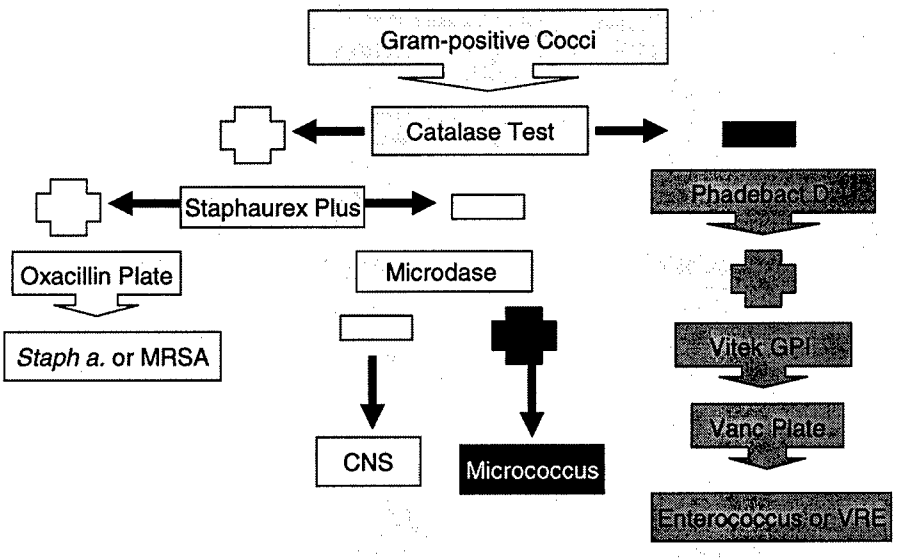
1.DBL refers to sequential culturing of the same telephone during the same time period.
2. Control refers to the one control culture that was randomly selected for each culture batch.
3. BAP= blood agar plate
4. CAP= chocolate agar plate
5. MAC= MacConkey agar plates
6. CFU/cm^2 refers to the number of colony forming units identified per centimeter squared.
7. [(a)]= room cleaned prior to swab.

Figure 1 "Bacterial Identification Algorithm for *E. coli*"



**Algorithm was adapted from algorithms found in "The Textbook of Diagnostic Microbiology" (43)

Figure 2 "Bacterial Identification Algorithm for Gram-positive Cocci"



**Algorithm was adapted from algorithms found in "The Textbook of Diagnostic Microbiology" (43)

Chart 1 "Bacteria Cultured From Telephones"